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Middle of Eclipse.

$$\left\{\begin{array}{l}\cos\omega_0 = -\,3{\cdot}6099 - [1{\cdot}70562]\sin l + [1{\cdot}28293]\cos l\cos(\lambda - 65^\circ\ 21'\ 54'') \\ \mathrm{T}_0\ = 17^{\mathrm{h}}\ 42^{\mathrm{m}}\ 6^{\mathrm{s}} - [3{\cdot}40989]\sin l - [3{\cdot}95954]\cos l\cos(\lambda - 23^\circ\ 24'\ 14'')\end{array}\right.$$

$$\text{Semi-duration of Totality} = [2{\cdot}24130]\sin\omega.$$

Last Contact.

$$\left\{\begin{array}{l}\cos\omega_4 = -\,0{\cdot}01944 - [0{\cdot}23592]\sin l + [9{\cdot}89559]\cos l\cos(\lambda - 36^\circ\ 18'\ 30'') \\ \mathrm{T}_4 = 16^{\mathrm{h}}\ 53^{\mathrm{m}}\ 21^{\mathrm{s}} + [3{\cdot}73564]\sin\omega_4 - [3{\cdot}55759]\sin l - [3{\cdot}98439]\cos l\cos(\lambda - 1^\circ\ 14'\ 33''.)\end{array}\right.$$

Continuation of the Central Line and Limits of Totality across the Bay of Bengal and the Malay Peninsula. 1st *Approximation.*

Greenwich Mean Time.	Northern Limit.		Central Line.		Southern Limit.		Remarks.
	Latitude. N.	Longitude. E.	Latitude. N.	Longitude. E.	Latitude. N.	Longitude. E.	
h m	° ′	° ′	° ′	° ′	° ′	° ′	
16 20	16 56	83 53	15 54	83 47	14 52	83 38	The Second approximation would not shift these lines much. The points would be moved along the lines chiefly, so that the effect would be a change of time.
16 25	16 38	85 57	15 36	85 49	14 33	85 38	
16 30	16 16	87 55	15 14	87 46	14 12	87 37	
16 35	15 51	89 48	14 50	89 38	13 48	89 28	
16 40	15 25	91 36	14 23	91 25	13 21	91 14	
16 45	14 56	93 20	13 55	93 8	12 53	92 57	
16 50	14 25	95 1	13 24	94 48	12 22	94 36	
16 55	13 51	96 38	12 51	96 25	11 50	96 12	
17 0	13 17	98 14	12 16	98 0	11 15	97 46	
17 5	12 40	99 47	11 40	99 33	10 39	99 19	
17 10	12 2	101 19	11 1	101 4	10 0	100 49	

On the Spectrum of Mars, with some Remarks on the Colour of that Planet. By William Huggins, Esq., F.R.S.

On several occasions during the late opposition of *Mars*, I made observations of the spectrum of the solar light reflected from that planet.

The spectroscope which I employed was the same as that of which a description has appeared in my former papers.* Two instruments were used, one of which is furnished with a

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* "On the Spectra of some of the Fixed Stars." *Phil. Trans.* 1864, p. 415. During my prismatic researches I have tried, and used occasionally, several other arrangements for applying the prism to the telescope. Some of these instruments are fitted with compound prisms, which give direct vision. I have not found any apparatus equal in delicacy and in accuracy to that which is referred to in the text.

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single prism of dense glass, which has a refracting angle of 60°. The other instrument has two similar prisms.

In a paper "On the Spectra of some of the Fixed Stars," by myself and Dr. W. A. Miller, we state that on one occasion several strong lines of absorption were seen in the more refrangible parts of the spectrum of *Mars*.

During the recent more favourable opportunities of viewing *Mars*, I again saw groups of lines in the blue and indigo parts of the spectrum. However, the faintness of this portion of the spectrum, when the slit was made sufficiently narrow for the distinct observation of the lines of Fraunhofer, did not permit me to measure with accuracy the position of the lines which I saw. For this reason I was unable to determine whether these lines are those which occur in this part of the solar spectrum, or whether any of them are new lines due to an absorption which the light suffers by reflection from the planet.

I have confirmed our former observation that several strong lines exist in the red portion of the spectrum. Fraunhofer's C was distinctly seen, and its identity determined by satisfactory measures with the micrometer of the spectrum apparatus. From this line the spectrum, as far as it can be traced towards the less refrangible end, is crossed by dark lines. One strong line was satisfactorily determined by the micrometer to be situated from C, at about one-fourth of the distance from C to B. As a similar line is not found in this position in the solar spectrum, the line in the spectrum of *Mars* may be accepted as an indication of absorption by the planet, and probably by the atmosphere which surrounds it. The other lines in the red may be identical, at least in part, with B and a, and the adjacent lines of the solar spectrum.

On February 14, faint lines were seen on both sides of Fraunhofer's D. The lines on the more refrangible side of D were stronger than the less refrangible lines. These lines occupy positions in the spectrum apparently coincident with groups of lines which make their appearance when the Sun's light traverses the lower strata of the atmosphere, and which are therefore supposed to be produced by the absorption of gases or vapours existing in our atmosphere. The lines in the spectrum of *Mars* probably indicate the existence of similar matter in the planet's atmosphere. I suspected that these lines were most distinct in the light from the margin of the planet's disk, but this observation was to some extent uncertain. That these lines were not produced by the portion of the Earth's atmosphere through which the light of *Mars* had passed was shown by the absence of similar lines in the spectrum of the Moon, which at the time of observation had a smaller altitude than *Mars*.

I observed also the spectra of the darker portions of the planet's disk. The spectrum of the dark zone beneath the Southern Polar spot appeared as a dusky band when compared

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with the spectra of the adjoining brighter parts of the planet. This fainter spectrum appeared to possess a uniform depth of shade throughout its length. This observation would indicate that the material which forms the darker parts of the planet's surface, absorbs all the rays of the spectrum equally. These portions should be therefore neutral, or nearly so, in colour.

I do not now regard the ruddy colour of *Mars* to be due to an *elective* absorption, that is an absorption of certain rays only so as to produce dark lines in the spectrum.

Further, it does not appear to be probable that the ruddy tint which distinguishes *Mars* has its origin in the planet's atmosphere, for the light reflected from the polar regions is free from colour, though this light has traversed a longer column of atmosphere than the light from the central parts of the disk. It is in the central parts of the disk that the colour is most marked. If indeed the colour be produced by the planet's atmosphere, it must be referred to peculiar conditions of it which exist only in connexion with particular portions of the planetary surface. The evidence we possess at present appears to support the opinion that the planet's distinctive colour has its origin in the material of which some parts of its surface are composed. Mr. Lockyer's observation that the colour is most intense when the planet's atmosphere is free from clouds obviously admits of an interpretation in accordance with this view.

This opinion appears to receive support from the photometric observations of Seidel and Zöllner, some of the results of which I will briefly state.

These observations show that *Mars* resembles the Moon in the anomalous amount of variation of the light reflected from it, as it increases and decreases in phase; also in the greater brilliancy of the marginal portions of its disk. Further, Zöllner has found that the albedo of *Mars*, that is, the mean reflective power of the different parts of its disk, is not more than about one half greater than that of the lunar surface. Now these optical characters are in accordance with telescopic observation that in the case of *Mars* the light is reflected almost entirely from the true surface of the planet. *Jupiter* and *Saturn*, the light from which has evidently come from an envelope of clouds, are, on the contrary, less bright at the margin than at the central part of the disk. These planets have an albedo, severally, about four and three times greater than that of the Moon.*

The anomalous degradation in brightness of the Moon at the phases on either side of the full, as well as the greater brilliancy of the limb, may be accounted for by the supposition of inequalities on its surface, and also by a partly regular reflective property of its superficial rocks. Zöllner has shown that if these phenomena be assumed empirically to be due to inequalities, then the angle of mean elevation of these inequalities must be taken as 52°. On the same hypothesis the more rapid changes of *Mars* would require an angle of 76°.*

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* *Photometrische Untersuchungen*, von Dr. J. C. Zöllner, Leipzig, 1865.

It appears to be highly probable that the conditions of surface which give rise to these phenomena are common to the Moon and to *Mars*. The considerations referred to in a former paragraph suggest that these superficial conditions represent peculiarities which exist at the true surface of the planet. In this connexion it is of importance to remark that the darker parts of the disk of *Mars* gradually disappear, and the coloured portions lose their distinctive ruddy tint as they approach the limb.

The observations of Sir John Herschel† and Prof. G. Bond‡ give a mean reflective power to the Moon's surface, similar to that from a "grey, weathered sandstone" rock. Zöllner has confirmed this statement. According to him,—

The albedo of the	Moon	= ·1736	of the incident light.	
,,	Mars	= ·2672	,,	,,
,,	Jupiter	= ·6238	,,	,,
,,	Saturn	= ·4981	,,	,,
,,	White Paper	= ·700	,,	,,
,,	White Sandstone	= ·237	,,	,,

From this table it appears that *Mars* takes in for its own use ·7328 of the energy which it receives as light. *Jupiter's* cloudy atmosphere, nearly as brilliant as white paper, rejects more than six-tenths of the light which falls upon it. Therefore, less than four-tenths of the light which this distant planet receives is alone available for the purposes of its economy.

The photographic researches of Mr. De La Rue and others show that the rays of high refrangibility, which are specially powerful in producing chemical action, are similarly affected.§ At present we know nothing of the reflective power of the planets for those rays of slower vibration, which we call heat.

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[*] *Photometrische Untersuchungen*, von Dr. J. C. Zöllner, Leipzig, 1865, pp. 113, 128.

[†] *Outlines of Astronomy*, p. 272.

[‡] "On the Light of the Moon, and *Jupiter*," *Memoirs Amer. Academy*, vol. viii. p. 222. In the same Memoir Prof. G. Bond estimates the albedo of *Jupiter* to be greater than unity. This estimate would require the admission that *Jupiter* shines in part by native light. Ibid. p. 284.

[§] Prof. G. Bond states that "the Moon, if the constitution of its surface resembled that of *Jupiter*, would photograph in *one fourteenth* of the time it actually requires." Ibid. p. 223.